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THE INFLUENCE OF STEAM TEACHING ACTIVITIES INTEGRATING LOCAL ENVIRONMENTAL AWARENESS ON UNIVERSITY STUDENTS' PRO-ENVIRONMENTAL BEHAVIOR AND SCIENTIFIC CREATIVITY

Chin-Fei Huang

Abstract. *This study aims to explore the impact of STEAM teaching activities that incorporate local environmental awareness on university students' pro-environmental behavior (PEB), and scientific creativity. The teaching activity design of this study was centered on "designing livable housing in Taiwan", and a total of four projects were designed. This research included university students (N=66) who were divided into a control group (n=33) and an experimental group (n=33). The experimental group added videos on local environmental awareness such as "local disasters and local household interview news". The students were required to fill out the "Scientific Creativity Questionnaire" and "PEB Scale" before and after the teaching activities. The results of the study indicate that the experimental group outperformed the control group in the post-test for the sub-dimensions of "Green Behavior," "Global Warming Awareness," "Environmental Social Interaction," "Informal Environmental Education," and "Environmental Attitude." This suggests that incorporating local environmental awareness materials into STEAM teaching activities is more effective in enhancing university students' PEB compared to standard STEAM teaching activities. Additionally, both groups showed improvements in overall scientific creativity after participating in the different activities, particularly in the areas of fluency and flexibility. However, ANCOVA analysis revealed no significant difference in scientific creativity between the two groups in the post-test. The results indicated that the integration of local environmental awareness materials was not the primary factor contributing to improvements in scientific creativity. This study recommends that higher education lectures integrate both environmental awareness and scientific content into curriculum design to strengthen students' overall competencies.*
Keywords: *local environmental awareness, quantitative research, pro-environmental behavior (PEB), scientific creativity, STEAM*

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Introduction

The main function of education is to inherit the past and inspire the future. In other words, education should have two main axes. The first is to guide learners to understand the knowledge base of predecessors and apply it to the present. The second is to open learners up to exploring the vision of a future world, and then to assist the common sustainable development of human beings and nature (Author, 2021; Quigley et al., 2019).

In other words, relying solely on existing logical frameworks and knowledge dimensions is insufficient for proposing innovative survival strategies to address environmental changes. At the university stage, students are facing the critical point of "accepting higher education knowledge and ability cultivation" and "independently exploring the future world". Improving university students' multi-faceted knowledge through education and enhancing cross-field knowledge to address future environmental challenges are urgent educational tasks in the contemporary era. However, to face the unknown environmental problems, it is worth discussing whether people with higher scientific knowledge or people with more positive pro-environmental behavior (PEB) can solve problems better.

Yeh et al. (2021) demonstrated that students who achieved higher scores in environmental science also tended to perform better in the environmental problem-solving (EPS) process. However, the students with higher scores in PEB can provide more creative ideas for solving environmental problems, though many of these ideas might be highly imaginative or impractical. The findings show that it is very important to continuously track and discuss the interaction between students' PEB and scientific ability. Furthermore, the previous studies mentioned that scientific creativity is a specific science ability to solve unknown or future problems (Author, 2019; Huang et al., 2017). On the whole, laying the foundation of scientific knowledge and cultivating students' scientific creativity will be the top priority of higher education. To sum up, cultivating talents who possess both PEB and scientific creativity may be the key to solving unknown environmental problems in the future.

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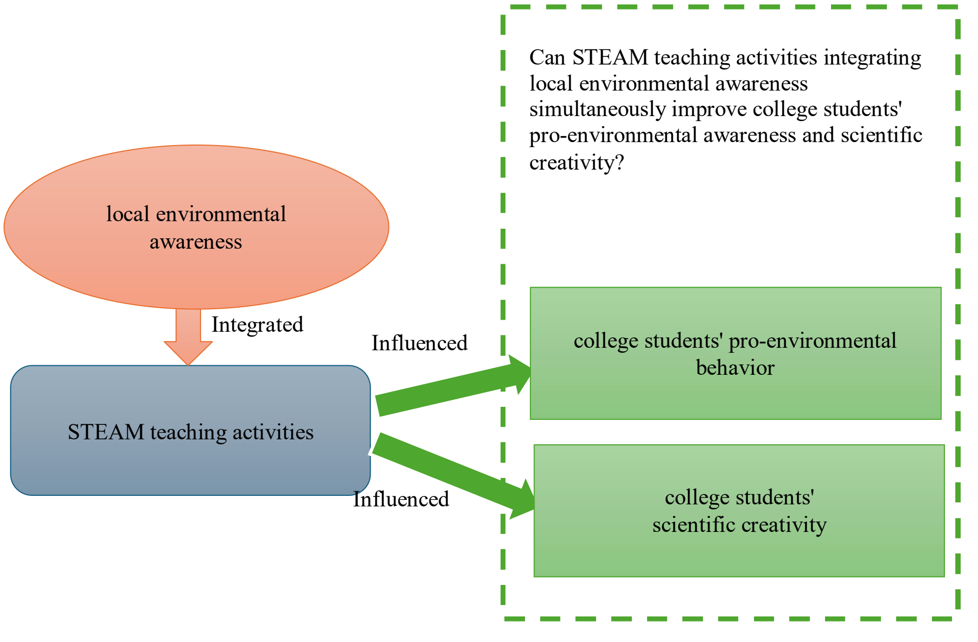
Therefore, what kind of teaching activities are expected to enhance university students' PEB and scientific creativity? Considering the future prospects of education, designing an integrated curriculum that combines "local environmental awareness" and "scientific thinking" may represent a forward-looking teaching model. Besides, since the participants in this study are from Taiwan, and the local environmental issues in Taiwan include typhoons, earthquakes, and landslides, this study adds these local environmental issues to the research design and tries to connect them with the participants' daily life experiences.

To achieve the goals of the above-mentioned multi-disciplinary and interdisciplinary education, the STEAM (Science, Technology, Engineering, Art, Mathematics) teaching concept will be a very appropriate strategy to connect overall scientific ability with practical environmental problem solving. In recent years, many scholars have proposed through empirical research that STEAM is a good strategy to guide learners to integrate knowledge across domains (Conradty & Bogner, 2018; Nguyen, et al., 2020; Perignat & Katz-Buonincontro, 2019; Thuneberg et al., 2018). The significance of this teaching strategy is to guide students to apply the connotations of science, technology, engineering, art, mathematics, and other knowledge to the real world, facilitating cross-disciplinary integrated learning. It can be seen that STEAM education has the elements of cross-disciplinary integrated thinking and focuses on the reality of environmental issues. It is one of the anchors to guide the goals of future science and environmental education.

Figure 1
Research Framework



Local Environmental Awareness and STEAM Education

Exploring the separation and merger of local environmental awareness and science education is not a topic that has only been discussed in recent years. It can be found in Freire's (1970) research, in which he advocated that the so-called humanistic perspective is to reflect on one's own role in the environment and cultural context according to the changes in the world environment and cultural context, and to exert the value of one's existence through ideas and practices. In other words, each generation should be keenly aware of the direction and needs of the contemporary local environment and cultural context, and make valuable self-contributions. This is local environmental awareness in a broad sense.

Klopfer and Aikenhead (2022) reviewed and analyzed the past 70 years of humanistic-oriented research in science education. They believed that the connotation of science education covering humanistic concepts is that

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people, through their own culture, values, local environmental awareness, and social interaction, construct their own cross-disciplinary multi-scientific views. These cultures, values, environmental sensitivity and social interaction are based on a humanistic perspective. Finally, people apply the evidence and new discoveries obtained from their own scientific views to culture, society and the environment, economy and other future trends. In other words, integrating local environmental awareness into STEAM education is indeed a feasible teaching strategy.

In line with the above definition, in recent years, the combination of STEM education, which focuses on cross-field integration and life application, and local environmental awareness will be the integration of science and humanistic awareness, and it will also be one of the development trends of future education.

STEM education integrates science, technology, engineering, mathematics and other interdisciplinary knowledge, and gradually forms the overall scientific ability dynamically, so as to acquire the ability of individuals to survive in the future world (Nguyen et al., 2020; Thuneberg et al., 2018). Although the essence of STEM education has already covered cross-field integrated thinking, many scholars believe that in addition to the integration of knowledge and ability, the future education model needs to be creative in order to break through the established thinking mode and solve unknown future problems. The creativity part can be supplemented by "A (art)" in STEAM (Conradty & Bogner, 2018; Perignat & Katz-Buonincontro, 2019; Runco et al., 2017; Thuneberg et al., 2018). Through the analysis and definition of the above literature, it can be found that STEAM education not only has the cross-disciplinary integrated thinking of STEM education, but also covers the elements of creativity. Therefore, this study hypothesizes that STEAM teaching activities integrated with local environmental awareness will have separate effects on university students' PEB and scientific creativity.

Analysis of the Essence of PEB

In order to learn to coexist with the current earth and achieve a balance of sustainable development, people all over the world need interdisciplinary education to solve real-world problems (Ballew et al., 2015; Chankrajang & Muttarak, 2017). In order to explore the differences in people's performance in the real and complex environmental dimension, Spanish scholar Varela-Candamio et al. (2018) conducted a theoretical analysis through multiple humanistic perspectives and environmental factors, called the Pro-Environmental Behavior (PEB) theoretical framework and empirical research put forward a new point of view. The PEB defined by Varela-Candamio et al. refers to individuals' behavior choices driven by concern for environmental protection. PEB may be influenced by social norms or legal constraints, but it can also stem from individuals' intrinsic values. Based on the aforementioned definition, Varela-Candamio and others pointed out that the influencing factors that can make people pay more attention to the real social environment include six levels, namely "awareness", "attitude", "intention", "motivation", "social norms", and "education". These six levels also include 10 items, namely pro-social motivations (NAT), environmental concern (NEP), self-interest and reasoned action (TPB), habit and emotions (TIP), prevention (PMT), self-efficacy (CTS), social life (ST), social norms (FTNC), social identity (SIT) and knowledge (ACA) (Ballew et al., 2015; Boyes & Stanisstreet, 2012; NAAEE, 2011; Shamuganathan & Karpudewan, 2017). Varela-Candamio et al. (2018) developed a 5-point Likert scale with an average of three questions for each item, a total of four background items and 47 formal items.

Therefore, the essence of PEB emphasizes how individuals' choices in daily life can have a positive influence on the environment. Education plays a crucial role in shaping these behavioral patterns, particularly environmental education, which enhances awareness of environmental problems, imparts problem-solving skills, and fosters critical thinking, enabling individuals to make more responsible decisions. Accordingly, the local environment in which individuals reside influences their final decisions regarding PEB. In summary, integrating local environmental awareness into education can be assessed through the manifestation of PEB. The definition of PEB aligns with the core concepts of this study and can serve as a reference for evaluating its performance.

Scientific Creativity

Research on creativity has been carried out since the 1950s (Guilford, 1950), and there are still many scholars involved in related research (Author, 2019; Yang et al., 2016). Recently, Ozkan and Topsakal (2021) reiterated that creativity is one of the most important items for cultivating students' future abilities, and students' creativity can be enhanced through STEAM cross-disciplinary courses. So, what is the definition of creativity?

Guilford (1950) believed that creativity is a kind of mental ability with novel thinking, and people with high levels of creativity can show novel and valuable thinking processes and works. Rhodes (1961) further classified creativity into the 4P theory, including person, process, product, environment or pressure (place or press). After

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nearly 50 years of research on creativity, Mayer (1999) compiled the definition and orientation of creativity, agreeing that it is the mental ability of novel thinking.

Although the above theories can all express the process and display of individual creativity, through the statement and discussion of multiple intelligences, Gardner (1993) pointed out that creativity is a part of multiple intelligences. Following Gardner's argument, Csikszentmihalyi (1996) then pointed out that creativity can be differentiated into general creativity and domain-specific creativity. In other words, general creativity does not involve a specific domain of knowledge or domain of knowledge interaction, while domain-specific creativity varies with domain background knowledge and skills.

On the whole, the difference between creativity and scientific creativity lies in whether the creativity includes the essence and components of scientific knowledge. When discussing general creativity, it does not necessarily require a scientific context. However, when addressing scientific creativity, it is essential to focus on creation. From a performance perspective, it must encompass the core principles of scientific knowledge. As far as this study is concerned, the goal is to focus on the reference of performance at the "scientific level," so the definition of scientific creativity is more in line with the goal of this study.

In evaluating the performance of scientific creativity, the "Scientific Creativity Questionnaire (SCQ)" developed by Hu and Adey (2002) has been widely used in recent years. Moreover, the study by Huang and Wang (2019) further validated the strong predictive power of the SCQ for scientific creativity performance.

To sum up, based on the paper review and analysis, this study:

- Hypothesizes that STEAM teaching activities integrated with local environmental awareness will have separate effects on university students' PEB and scientific creativity;
- Adopts a PEB theory framework to define the performance of "local environmental awareness";
- Chooses the SCQ as the research instrument to measure the participants' scientific creativity.

Research Aim and Research Questions

Although the concept of STEAM covers a wide range of cross-domain educational thinking, there is still little literature on local environmental awareness. Therefore, this study aimed to develop a set of STEAM teaching activities that integrate local environmental awareness to explore its influence on university students' behavior and creativity (the research framework is as Figure 1), guided by the following two specific research questions:

1. What is the influence of STEAM teaching activities integrating local environmental awareness on university students' pro-environmental behavior (PEB)?
2. What is the influence of STEAM teaching activities integrating local environmental awareness on university students' scientific creativity?

Research Methodology

General Background

This study employed a quasi-experimental research method, which allows experiments to be conducted without complete random assignment. The study draws inferences by comparing the results between the experimental and control groups. This method is well-suited for educational research conducted in real classroom settings. During the research process, a set of teaching activities with the theme of "Designing Livable Housing in Taiwan" was planned, which included a total of 4 weeks of teaching time (2 lessons per week, 60 minutes per lesson, a total of 480 minutes). The unit activities included "Designing an ideal livable house", "Using STEAM elements to evaluate and modify the house design", "Designing a livable house according to their own ideas" and "Designing a livable house suitable for the environment in Taiwan". The control group was only taught and discussed from a scientific perspective in the activity of "Designing a livable house according to their own ideas", while the experimental group added local environmental awareness videos such as "Local Disasters and Local Resident Interview News". In the process of this study, the scientific creativity and PEB performance of the experimental group and the control group were collected before and after the test results in order to understand the impact of the teaching activity on the scientific creativity and PEB performance of university students. In addition, this study also uses data analysis to explore the influence of "incorporating local environmental awareness teaching materials" on university students' scientific creativity and PEB performance (Table 1).

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Table 1
The Research Design Comparison

Group	Pre-test		"Designing Livable Housing in Taiwan" Teaching Activities				Post-test	
	PEB scale	SC test	Designing Livable Homes	Make good use of STEAM elements to evaluate and modify house design	Integrate local environmental awareness	Building livable houses suitable for Taiwan's environment	PEB scale	SC test
Control Group	V	V	V	V	X	X design a livable house according to their own ideas)	V	V
Experimental group	V	V	V	V	O (Add videos from humanistic perspectives such as "Local Disasters and Local Household Interview News")	O (design a livable house considering Taiwan's environment)	V	V

Note: "V" indicates that the experimental group and the control group received the same teaching content. "X" indicates the use of general teaching content. "O" indicates the use of a teaching method that integrates local environmental awareness or issues.

The teaching design of this study was mainly designed with reference to the research perspectives of Ozkan and Topsakal (2021) and Perignat and Katz-Buonincontro (2019). According to the research of Perignat and Katz-Buonincontro, teaching activities designed based on the essence of STEAM should include six steps, namely "Experiencing an idea," "Coming up with an idea", "Planning and design fusion", "Making or synthesizing", "Testing", and "Evaluation." In this study, the above six steps were included in the teaching design for planning.

In addition, Perignat and Katz-Buonincontro (2019) reviewed and analyzed 44 STEAM-related articles, and proposed a STEAM teaching example with the theme of "building a suitable house" for a total of 8 hours. This teaching example is guided step by step, from the design conception, practicability, model making and testing of the house, to guiding students to reflect on the global link. The six steps are very consistent and suitable as a reference to design the STEAM teaching activities of this study.

Based on the above, this study referred to the six steps of STEAM teaching by Ozkan and Topsakal (2021), and the teaching paradigm of Perignat and Katz-Buonincontro to design a set of teaching activities called "Designing Livable Housing in Taiwan". The activity included a 4-week teaching schedule (2 classes per week, 60 minutes per class, 480 minutes in total), and considering Taiwan's environmental reality and cultural habits, the Perignat and Katz-Buonincontro teaching paradigm "Designing hurricane-resistant coastal houses and beach huts" was changed to "Building livable houses suitable for Taiwan's environment" in order to be more in line with the cognition of Taiwanese students and the current environment. The connotation and implementation process details of the STEAM teaching activity "Designing Livable Housing in Taiwan" in this study are shown in Table 2.

Table 2
The Teaching Process of STEAM Teaching Activities with the Theme of "Designing Livable Housing in Taiwan"

Week	Teaching Aims	Session	Content (Perignat & Katz-Buonincontro, 2019)	STEAM	Six Steps (Ozkan & Topsakal, 2021)
1	Designing your dream livable home	1	Explain the structure and space planning of architectural mechanics, and stimulate students' creative imagination of livable houses.	S: mechanics E: structure A: design art	Experiencing an idea
		2	Through group discussion, students design the appearance and interior space of a livable house by themselves. Each group uses 3 floors and 82.5 square meters of interior space on each floor as the planning basis.	S: space concept E: structure A: design art M: unit conversion	idea generation integrated with planning and design fusion

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2	Make good use of STEAM elements to evaluate and modify house design	3	Students use creativity to find materials and tools, or make good use of technology to build model houses.	S: material science T: technology materials E: structure	Making or synthesizing
		4	Each group discusses the house material data collected in the previous week, and evaluates and modifies the house design based on STEAM elements.	Self-assessment	Testing Evaluation
3	Integrate local environmental awareness	5 6	Teach students to learn scientific knowledge about the local environment, such as common typhoons, earthquakes, landslides, etc. in Taiwan, and master how to respond to these climatic conditions to build livable houses. The control group only conducted teaching and discussion from a scientific perspective, while the experimental group added "local disasters and local household interview news", "such as news clips of the Morakot Typhoon disaster and the "921" earthquake (1999 September, 21) news clips in Taiwan.	S: weather science T: information media E: structural mechanics M: Disaster calculation and model building	Planning and design fusion Testing Evaluation
4	Building livable houses suitable for Taiwan's environment	7	Test the house model and modify the house design to match the local environment in Taiwan.	Self-assessment	Testing Evaluation
		8	Use critical thinking to evaluate work and produce group reflective reports.	communication and expression	

After the planning of this teaching activity was completed, five experts were invited to review the teaching content. The meeting method was used to obtain the consensus of the experts on the content of the teaching activity, so as to establish the final version of the teaching content.

Participants

The lecture in this study was a full-time environmental education professor with 10 years of teaching experience. The participants of this study were 66 students from a university in southern Taiwan who were enrolled in General Education courses. In order to avoid excessive interference with the course operation of the school, the participants selected two General Education courses with 33 students in each class. These students came from different departments and had interdisciplinary backgrounds, but they have taken the same environmental education course, showing similar interests.

After the teacher and all the students agreed and signed the research informed consent, the teaching activities lasted for 4 weeks (May 30 to June 24, 2022). In this study, one of the classes was randomly assigned as the control group and the other as the experimental group (see Table 3).

Table 3
Participants Description Form

Group	Gender	*n*	Age (*M* ± *S.D.*)		Major
Control Group (*n=33*)	Male	18	23.4 ± .2.1	22.6 ± 2.1	Design Major (*N = 10*) Management Major (*N = 6*) Information Major (*N = 6*) Applied Society Major (*N = 11*)
	Female	15	21.5 ± 1.5		
Experimental Group (*n=33*)	Male	12	21.3 ± 1.8	21.3 ± 1.5	Design Major (*N = 12*) Management Major (*N = 8*) Information Major (*N = 3*) Applied Society Major (*N = 10*)
	Female	21	21.2 ± 1.4		
Total (*n=66*)	Male	30	22.6 ± 2.2	21.9 ± 1.9	Design Major (*N = 22*) Management Major (*N = 14*) Information Major (*N = 9*) Applied Society Major (*N = 21*)
	Female	36	21.4 ± 1.5		

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From Table 3, it can be found that the experimental group and the control group had the same number of students, and the average age and gender distribution were also similar. During the teaching process, the university students participating in this research were grouped into groups of four to five students. For all lecture periods during the research, students worked in the same groups.

Instrument and Procedures

The main research tools of this study were the PEB Scale and the Scientific Creativity Questionnaire. The PEB Scale refers to the scale designed by Varela-Candamio et al. (2018) which included six domains and 47 items. The six domains included "Energy Saving Attitude", "Global Warming Awareness", "Green Behavior", "Environmental Social Interaction", "Informal Environmental Education", and "Environmental Attitude". It is a 5-point Likert scale, where a higher score means more positive PEB. The scale was translated into Chinese by the author of this study, and three environmental education experts were invited to review the translated content to ensure content validity, and then to conduct a reliability test. The reliability of the scale reached Cronbach's α .93, showing that it had high reliability.

This study adopted the SCQ developed by Hu and Adey (2002) as one of the research instruments to evaluate the participants' scientific creativity performance. The original version of this questionnaire was translated into Chinese, and three science education experts were invited to conduct a reliability test after reviewing the translated content to ensure content validity. Take the first item of SCQ as an example; the question asks participants to answer, "Please write down as many possible scientific uses as you can for a piece of glass". The reliability of the scale reached Cronbach's α .87, showing that it had high reliability.

The scoring method of this Scientific Creativity Questionnaire was also based on the recommendations of the original literature, that is, fluency (the number of answers for each question), flexibility (the number of concept categories and types of each answer), originality (the number of answers for each answer in relation to the occurrence rate in the group) as an indicator of scoring (as shown in Table 4). The higher the total score, the better the performance of scientific creativity.

Table 4
Scoring Method for the Scientific Creativity Questionnaire

Scoring Method for the Scientific Creativity Questionnaire		
	Item	**Scoring Method**
Score Standard	Fluency	1 point for each answer filled in, and the number of answers for each question is summed up.
	Flexibility	After classifying all the answers into concept categories, sum up the totals of all categories.
	Originality	Unique creative answer: (1) A score of 0 is given for each answer that appears in more than 10% of the number of subjects (2) 1 point for each answer occurring in 5% to 10% of the subjects (3) 2 points are given for each answer whose occurrence rate is less than 5% of the number of subjects

Data Analysis

According to the above-mentioned scales and questionnaires, data distribution and collection were carried out according to the experimental group and the control group. A total of 66 copies of the PEB Scale and the Scientific Creativity Questionnaire were distributed before and after the test. The recovery rate was 100%. All quantification data analysis was performed using SPSS 27.0. The paired *t*-test and ANCOVA were used to analyze the results.

Research Results

Local environmental awareness can improve university students' PEB

The research process was designed according to the research purpose. The control group students were asked to perform STEAM teaching activities, while the experimental group students were given STEAM teaching activi-

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ties integrated with local environmental awareness. After collecting the pre- and post-test data of the PEB Scale, and using the paired sample *t*-test analysis, it was found that, regardless of the control group or the experimental group, after the teaching activities, their PEB performance was better than before participating in the teaching activities (Table 5). The results show that the above two teaching activities can improve the performance of university students' PEB.

Table 5

Paired Sample t-test Analysis of Pre-test and Post-test Total Scores of PEB Performance in Different Groups

Group (Number)	PEB Score	*M* ± *SD*	*t*	*p*
Control Group (*n*=33)	Pre-test	3.72 ± 0.46	- 4.87	< .001
	Post-test	4.05 ± 0.19		
Experimental Group (*n*=33)	Pre-test	3.69 ± 0.57	6.58	< .001
	Post-test	4.23 ± 0.27		
Total (*N*=66)	Pre-test	3.71 ± 0.51	-7.98	< .001
	Post-test	4.14 ± 0.25		

ANCOVA was used to compare the control group and the experimental group. The results showed that the post-test performance of the control group and the experimental group was significantly different (Table 6). Looking at the pre-test and post-test total scores of the control group and the experimental group (Table 5), it can be found that the overall PEB of the experimental group was better than that of the control group after participating in the STEAM teaching activities integrating local environmental awareness.

Table 6

ANCOVA Analysis of the PEB Performance of the Control Group and the Experimental Group

Source	*SS*	*df*	*MS*	*F*	*p*
Corrected Model	1.646a	2	.823	22.138	< .001
Intercept	12.320	1	12.320	331.477	< .001
Pre-test	1.108	1	1.108	29.808	< .001
Group	.594	1	.594	15.971	< .001
Error	2.342	63	.037		
Total	1133.038	66			
Corrected Total	3.987	65			

Table 6 shows that the STEAM teaching activities integrating local environmental awareness were more conducive to improving university students' PEB performance than the STEAM teaching activities on their own. However, the PEB scale included six dimensions, in order to clarify the performance differences between the control group and the experimental group in these different dimensions, paired sample *t* tests (Table 7) and ANCOVA analysis were conducted for each dimension to compare the two groups of research subjects.

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Table 7

Paired Sample t-test Analysis of Pre-test and Post-test Performance in all Dimensions of PEB for the Control Group and the Experimental Group

PEB Domain	Group	Experiment	*M ± SD*	*t*	*p*
Energy Saving Attitude	Control Group (*n* = 33)	Pre-test	3.70 ± 0.55	-6.43	< .001
		Post-test	4.08 ± 0.37		
	Experimental Group (*n* = 33)	Pre-test	3.64 ± 0.61	-3.25	.003
		Post-test	4.12 ± 0.77		
Global Warming Awareness	Control Group (*n* = 33)	Pre-test	4.00 ± 0.50	-2.17	.038
		Post-test	4.19 ± 0.48		
	Experimental Group (*n* = 33)	Pre-test	3.67 ± 0.67	-8.31	< .001
		Post-test	4.41 ± 0.34		
Green Behavior	Control Group (*n* = 33)	Pre-test	3.80 ± 0.69	-1.70	.098
		Post-test	4.02 ± 0.30		
	Experimental Group (*n* = 33)	Pre-test	3.87 ± 0.71	-2.69	.011
		Post-test	4.15 ± 0.47		
Environmental Social Interaction	Control Group (*n* = 33)	Pre-test	3.39 ± 0.67	-5.04	< .001
		Post-test	4.00 ± 0.40		
	Experimental Group (*n* = 33)	Pre-test	3.30 ± 0.76	-7.19	< .001
		Post-test	4.27 ± 0.25		
Informal Environmental Education	Control Group (*n* = 33)	Pre-test	4.06 ± 0.73	.718	.478
		Post-test	3.97 ± 0.50		
	Experimental Group (*n* = 33)	Pre-test	4.22 ± 0.75	-.271	.788
		Post-test	4.25 ± 0.45		
Environmental Attitude	Control Group (*n* = 33)	Pre-test	3.75 ± 0.54	-3.02	.005
		Post-test	4.05 ± 0.41		
	Experimental Group (*n* = 33)	Pre-test	3.80 ± 0.74	-4.15	< .001
		Post-test	4.29 ± 0.28		

It can be found from Table 7 that after participating in the teaching activities, the participants' environmental behavior scored higher than before on the four proficiency levels of "Energy Saving Attitude", "Global Warming Awareness", "Environmental Social Interaction", and "Environmental Attitude". It shows that regardless of whether it is integrated into local environmental awareness or not, STEAM teaching activities can positively trigger university students' "Energy Saving Attitude", "Global Warming Awareness", "Environmental Social Interaction", and "Environmental Attitude". On the contrary, there was no significant difference in the performance of the pre-test and post-test of the two groups in the dimension of "Informal environmental education".

It is worth noting that in the dimension of "Green Behavior," the average score of the post-test in the experimental group was higher than that of the pre-test, with a significant difference, while the average scores of the pre-test and post-test of the control group did not reach a significant difference. The results show that STEAM teaching activities integrating local environmental awareness were more helpful to improve university students' "Green Behavior" performance than the STEAM teaching activities.

ANCOVA comparisons were then conducted for the different sub-dimensions, using the pre-test total score

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of each sub-dimension as a covariate item and the post-test total score as a dependent variable. The results of the analysis showed that in the dimension of Energy Conservation Attitude, there was no significant difference between the two groups (F = .30; p = .586). However, in the dimensions of "Global Warming Awareness" (F = 15.31; p < .001), "Environmental Social Interaction" (F = 11.42; p = .001), "Informal Environmental Education" (F = 5.02; p = .029) and "Environmental Attitude" (F = 7.76; p = .007), the post-test performance of the experimental group was better than that of the control group, and there was a significant difference.

Integrating the above research results, it can be found that after university students carry out STEAM teaching activities integrating local environmental awareness, their overall PEB performance is better than that of those who only conduct STEAM teaching activities. Dimensions such as "Cultural Awareness", "Environmental social interaction", "Informal environmental education", and "Environmental attitude" also performed well.

STEAM can improve creativity, with or without local environmental awareness

In addition to exploring the above-mentioned pro-environmental behaviors of university students, pre-test and post-test data on the scientific creativity performance of students in the control group and the experimental group were collected for the different teaching activities. After using the paired sample t-test analysis, it was found that regardless of the control group or the experimental group, after the teaching activities, their scientific creativity performance was better than before participating (Table 8). The results indicated that no matter whether local environmental awareness is integrated into STEAM teaching activities or not, the activities can improve university students' performance of scientific creativity.

Table 8
Paired Sample t-test Analysis of the Total Score of Scientific Creativity Performance of the Control Group and the Experimental Group Before and After the Test

Group (Number)	Scientific Creativity scores	*M ± SD*	*t*	*p*
Control Group (n = 33)	Pre-test	44.45 ± 13.37	-7.183	< .001
	Post-test	60.82 ± 19.06		
Experimental Group (n = 33)	Pre-test	42.91 ± 12.84	-8.04	< .001
	Post-test	56.24 ± 16.19		
Total (n = 66)	Pre-test	43.68 ± 13.03	-10.53	< .001
	Post-test	58.53 ± 17.70		

ANCOVA was then used to compare the control group and the experimental group. The total score of scientific creativity was used to test the covariate items, and the total score of scientific creativity was used to test the dependent variables. The results showed that the post-test performance of the control group and the experimental group did not reach a significant difference (Table 9).

Table 9
ANCOVA Analysis of the Scientific Creativity Performance of the Control Group and the Experimental Group

Source	*SS*	*df*	*MS*	*F*	*p*
Corrected Model	11990.875	2	5995.437	45.097	< .001
Intercept	975.832	1	975.832	7.340	.009
Pre-test	11645.405	1	11645.405	87.595	< .001
Group	146.503	1	146.503	1.102	.298
Error	8375.564	63	132.945		
Total	246469.000	66			
Corrected Total	20366.439	65			

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Since the scoring standard dimensions of scientific creativity include "fluency", "flexibility", and "originality", in order to clarify the performance differences between the control group and the experimental group in different scoring standard dimensions, this study further focused on each dimension. The paired sample *t*-test (Table 10) and ANCOVA analysis of the two groups of research objects were carried out.

Table 10

Paired-sample t-test Analysis for the Performance of Each Scoring Standard Dimension of Scientific Creativity in the Control Group and the Experimental Group Before and After the Test

Scientific Creativity Domains	Group	Experiment	*M ± SD*	*t*	*p*
Fluency	Control Group (*n* = 33)	Pre-test	30.15 ± 9.09	-8.11	< .001
		Post-test	41.64 ± 12.43		
	Experimental Group (*n* = 33)	Pre-test	28.55 ± 8.87	-9.17	< .001
		Post-test	38.94 ± 11.31		
Flexibility	Control Group (*n* = 33)	Pre-test	14.15 ± 4.18	-5.52	< .001
		Post-test	18.48 ± 5.89		
	Experimental Group (*n* = 33)	Pre-test	13.61 ± 3.55	-5.49	< .001
		Post-test	16.94 ± 4.74		
Originality	Control Group (*n* = 33)	Pre-test	0.12 ± 0.42	-1.77	.086
		Post-test	0.45 ± 1.00		
	Experimental Group (*n* = 33)	Pre-test	0.48 ± 1.09	-1.34	.190
		Post-test	0.82 ± 1.45		

It can be seen from Table 10 that after the control group and the experimental group participated in the teaching activities, their fluency and flexibility in scientific creativity improved compared with the pre-test, and there was a significant difference. However, there was no significant difference between the two groups in the pre-test and post-test performance of originality. The results of the study show that both STEAM teaching activities can improve the performance of fluency and flexibility in university students' scientific creativity, regardless of whether the teaching materials of local environmental awareness are integrated or not.

Lastly, ANCOVA comparisons were conducted for different sub-dimensions, using the pre-test total score co-variant item and the post-test total score dependent variable item for each sub-dimension. The analysis results showed that in the three dimensions of "fluency" (F = .314; p = .577), "flexibility" (F = 1.10; p = .298) and "originality" (F = .43; p = .516), the performance of the two groups did not reach a significant difference. The results of the study once again show that whether or not the teaching materials of local environmental awareness were integrated into the activities had no effect on the performance of scientific creativity.

Discussion

The purpose of this study was to design STEAM teaching activities that integrate local environmental awareness and explore their influence on university students' PEB and scientific creativity. The findings of this study demonstrate that integrating local environmental awareness into teaching is more effective in enhancing university students' PEB. Notably, in the "Green Behavior" dimension, the post-test scores of the experimental group were significantly higher than their pre-test scores. These results are consistent with the findings of Mo et al. (2022), which highlight that university students' environmental behaviors are influenced by their cultural beliefs and social responsibility awareness. In other words, incorporating elements of local environmental awareness into the curriculum, such as news clips and environmental videos, can effectively promote pro-environmental actions among university students.

Additionally, the results of this study indicated that the experimental group showed significantly higher scores than the control group in the post-test for the dimensions of "Global Warming Awareness,""Environmental Social Interaction," "Informal Environmental Education," and "Environmental Attitude". The above research results can support the research findings of Southerland and Settlage (2022), who pointed out that when the problems faced by learners are related to

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real life, and the problem-solving strategies involve interdisciplinary science, culture, values, knowledge and practice, learners will strengthen their multi-faceted knowledge in all aspects and connect what they have learned with life applications. This finding can respond to the needs of the education scene, that is, it can help improve students' learning by combining real-life environmental conditions and problem solving. The research of Ngo and Phan (2019) pointed out that in response to global environmental changes and the information explosion, in order to achieve sustainable development in the dimensions of human and natural environment, ecology, society, and economy, it is necessary to have breakthrough thinking and creativity. The results of this study found that the curriculum design of this study can indeed achieve the above teaching goals.

Furthermore, the analysis of scientific creativity in this study revealed that both the control and experimental groups demonstrated significant improvements in fluency and flexibility after participating in the teaching activities. However, no significant differences were found between the two groups in terms of originality across the pre-test and post-test assessments. This result is supported by the research results of Cheng et al. (2022). In their study, the general creativity performance of elementary school students was explored through STEAM special activities, and found that after teaching STEAM special activities, students' divergent creativity performance could be improved. In this study, we further found that the fluency and flexibility of university students through STEAM teaching activities had improved, which can indirectly explain the improvement in the creativity of university students in multiple dimensions. Also, the previous study mentioned that a lot of educational connotations must face the mutual challenge and balance of the dual dimensions of humanities and science (James, 2020). The most effective problem-solving model for the future world can only be identified through the simultaneous integration of humanities and science (Cope & Kalantzis, 2020), with an emphasis on local environmental awareness as an essential aspect of humanistic values. Besides, the display of STEAM education is the display of interdisciplinary science, and this kind of interdisciplinary science could reflect the complex environmental issues better. Although the results of this study are partly similar to those of past studies, however, the STEAM teaching activities of this study did not achieve the effect of improving the students' originality.

Conclusions and Implications

An important mission of higher education is to guide students in developing holistic qualities, scientific reasoning, and social responsibility. Cultivating outstanding students and helping them connect with the real world is a core responsibility of higher education. In order to explore how to simultaneously cultivate university students' PEB and scientific creativity, this study designed STEAM teaching activities integrating local environmental awareness and explored their impact on university students' PEB and scientific creativity.

Compared with STEAM teaching activities, the integration of local environmental awareness materials can improve the PEB of university students. From the research results and discussion, it was found that the overall PEB of the university students after performing the STEAM teaching activities integrating local environmental awareness activities were better than those of students who only conducted the STEAM teaching activities. Furthermore, the post-test performance of the experimental group was better than that of the control group in the sub-dimensions of "Green Behavior", "Global Warming Awareness", "Environmental Social Interaction", "Informal Environmental Education" and "Environmental Attitude". The results indicate that, compared with STEAM teaching activities, the integration of local environmental awareness materials can improve the PEB of university students.

Whether local environmental awareness is integrated into STEAM teaching activities or not, the STEAM activities can improve university students' scientific creativity performance. From the research results and discussion, it was found that whether university students conducted the STEAM teaching activities integrating local environmental awareness or just the STEAM teaching activities, their overall scientific creativity performance was better than before participating, especially in terms of fluency and flexibility. Furthermore, after ANCOVA analysis, there was no significant difference in the two groups' post-test performance of scientific creativity, indicating that integrating teaching materials of local environmental awareness is not the main reason for the performance of scientific creativity.

This study initially examined the influence of STEAM teaching activities that integrate local environmental awareness on university students' PEB and scientific creativity through quantitative analysis. However, to gain a more nuanced understanding of how the dynamics within the curriculum affect these outcomes, it is recommended that future research incorporate qualitative methods to provide a deeper clarification. The environmental problems or issues are very complex. It is necessary to rely on people's dual science ability and environmental behavior to clarify environmental problems and try to solve them. A lot of environmental problems are not easy to solve using existing technology and require people's creativity to solve problems. That's the main idea why this study focused on exploring students' scientific creativity and PEB. The practical contributions and suggestions are that, the results of this study found that the design of STEAM teaching

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activities that incorporate local environmental awareness can simultaneously improve the PEB and scientific creativity of university students. Since the professional fields of universities are divided into details, many teachers usually teach humanities, environmental education and science education separately. This study suggested that higher education teachers can integrate the dual connotations of environmental awareness and science into their curriculum planning to strengthen the overall ability of university students. Furthermore, this study suggests that future researchers design localized lesson plans based on the specific environmental conditions of different countries. Future research is expected to investigate the implementation of localized curricula in different countries to determine whether the enhancement of university students' PEB and scientific creativity can be consistently achieved across diverse cultural contexts and local environmental issues. Finally, this study suggests that future researchers incorporate qualitative data to provide a more in-depth interpretation of the changes in university students' environmental behavior.

Limitations

The participants of this study were 66 university students who enrolled in General Education courses in the south of Taiwan. Those students' background knowledge and lifestyle patterns may have influenced the research outcomes. To objectively present the results, a comparison between a control group and an experimental group was conducted. However, the diverse backgrounds and lifestyle patterns of the students represent the real-world variables present in reality educational situation. Therefore, this study faithfully reports the findings while acknowledging these inherent variations.

Furthermore, the PEB defined by Varela-Candamio et al. refers to individuals' behavioral choices motivated by concern for environmental protection. Consequently, the study employs questionnaires to understand individuals' choices, rather than directly verifying their actions.

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